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eight lifted from the quarry are sometimes made up mostly of this form. In division C are several forms; a noticeable one has its fresh surface covered with mastoidal eminences; these when cut down by weathering leave a series of beautiful rings or concentric circles. Examples of this species are not unlike an inverted saucer in shape.

The species found in A may be collected at Chazy, N. Y., and at many localities in Vermont; those in B and C at their appropriate horizons at Isle La Motte, Vt. The form in B is incidentally largely distributed through the country and will be found when looked for in the tiled floors of almost every public building where Isle La Motte marble has been used. In museums, too, it will be found under title of "Isle La Motte banded limestone." The place above all others for display of *S. vagosum* is a little island, at the entrance of Button Bay, three miles south of Fort Cassin, Vt., where a layer 20 to 30 inches thick is exclusively of this form and *Columnaria alveolata*, H.

The following facts are evident: (1) the genus *Stromatocentrum* does not make its first appearance in the Black River; it is there rather in its decadence; (2) it appears in the lower Chazy, following close upon the *Cryptozoon*, and persists through the different divisions; (3) it cannot of itself be trusted as a safe indication of the Black River.

However, it should be noticed that *Stromatocentrum vagosum* is most frequently paired with *Columnaria alveolata*, and the presence of the two forms establishes beyond question the presence of the Black River.

DR. CALLAWAY AND THE PRODUCTION OF CRYSTALLINE SCHISTS BY DYNAMO- METAMORPHISM.

BY J. W. REDWAY, F.R.G.S., MT. VERNON, N.Y.

ABOUT fifteen years ago, while setting a piece of heavy mining machinery that revolved on a vertical shaft, work was brought to a stand by the discovery that the journal, intended as a chair and box for the cone-shaped bearing, was considerably too small. A speculative workman thought it might wear down to shape, however, and started the machinery. The experiment, though of doubtful success from a mechanical standpoint, was brilliantly successful in another light. The bearing and journal, both of drop-forged steel, were welded to each other and broke into a dozen pieces. The interesting point, however, was the fact that two forgings of laminated steel under the agency of heat were converted to a metamorphic form. At the surface of welding the laminated steel became crystalline, and even the parts at some distance became semi-crystalline. It was a fair illustration of what is now called dynamo-metamorphism.

In a very remarkable paper presented to the *Quarterly Journal* of the Geological Society of England, Mr. Charles Callaway, D. Sc., F.G.S., has published the result of his researches on the origin and formation of certain crystalline schists found in the Malvern Hills, in the west of England. A close study of these schists during a period of five years has brought Dr. Callaway to the conclusion that they were produced by a dynamo-metamorphosis not different in essential principles from the illustration described in the preceding paragraph. Ordinarily, metamorphism in rocks may be briefly described as the change that a sedimentary rock undergoes when subjected to intense pressure in the presence of heat and moisture. The rock becomes more or less crystalline, and there is a tendency from homogeneity to heterogeneity in mineral structure. The production of metamorphism by the

shearing of rock and the gradual sliding or movement of the one mass upon the surface of the other is called dynamo-metamorphism. Neither the name nor the idea originated with Dr. Callaway, but the thorough exposition the subject has received at his hands entitles him to a foremost place among the pioneers in this field of research, and the results he has obtained are an important step in advance in the field of dynamic geology.

The Malvern Hills are mainly composed of masses of igneous rock, granitic in character, the constituents chiefly considered being binary granite and two kinds of diorite. In certain localities there are exposed bands of crystalline schist, apparently as seams of subsequent intercalation but really cataclastic in origin. These seams are the shear-zones within which the schist-making process occurred. Aside from the normal metamorphism which took place, the chief factor seemed to be a distinct shearing movement that resulted in a fusion sufficiently complete to produce plasticity.

Among the mechanical changes was the transformation of diorite into mica-gneiss. In the process of transformation the pulverized mineral not infrequently passed through an intermediate stage of laminated grit that simulated a sediment. A still more interesting change was the injection of potash and potassium feldspar into diorite, and a similar transference of the corresponding sodium salts into granite. In still other cases, diorite and granite were mutually interlaced. Chlorite and ferric oxide produced by the decomposition of diorite were injected or infiltrated into the cracks, cleavage and shear-planes of crushed granite and often migrated to a considerable distance, giving rise to an interfoliation of chlorite and biotite with the quartz, feldspar, and muscovite of the resulting gneiss.

The mineral changes may be classified as (a) decomposition, (b) transition, and (c) reconstruction. The massive rocks pass into schists through a process of decomposition, followed and partly accompanied by a process of reconstruction, in which the newly-formed quartz and feldspar crystallize, after the secondary consolidation. The chief mineral changes of the schist-making process are (a) the replacement of orthoclase by quartz and muscovite; (b) of plagioclase by the quartz and muscovite; (c) of chlorite by biotite and white mica; (d) and of biotite by white mica. The liberation of potassium from the granite is sometimes accompanied by silicification of the veins and the production of garnets. The reconstruction of feldspar is also a prominent feature in the metamorphism.

Among the chemical changes the following are noteworthy: (a) the mutual transference of sodium and potassium compounds between diorite and granite, also previously noted among physical changes; (b) the removal of sodium, potassium, magnesium, calcium, aluminium and iron compounds when diorite is converted to gneissoid quartzite; (c) the retention of aluminium and the elimination of alkaline compounds when diorite is metamorphosed to muscovite.

Dr. Callaway's researches involved the preparation of about 500 thin sections of rock for study with the microscope, and a large number of chemical analyses. His hypotheses are bold and ingenious, involving metasomatism on a large scale. Subsequent investigations, however, have not disproved them; on the contrary they have been strongly confirmed. It is interesting, moreover, to compare the work of Dr. Callaway with that of Mr. Van Hise on the schists of the Penokee iron-bearing series (U. S. Geol. Survey, Rep. 1888 and 1889, pp. 429 et seq.). The ideas shadowed in Mr. Van Hise's report could not have been more fully confirmed than they have been by Dr. Callaway, working independently at the same time on rocks several thousand miles away.